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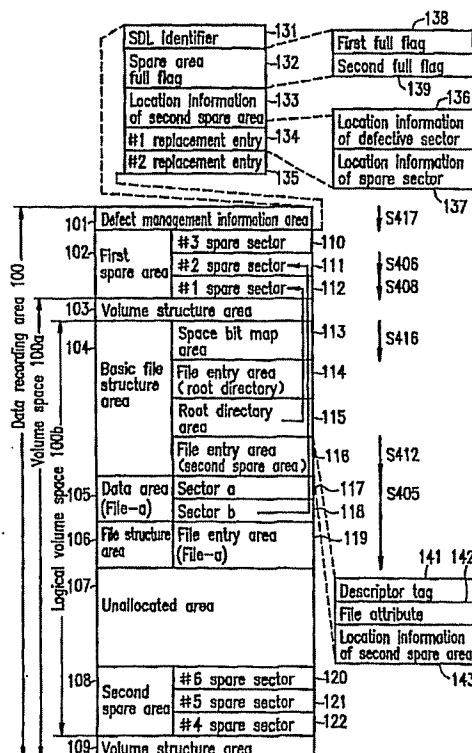
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(54) Title: INFORMATION RECORDING MEDIUM, INFORMATION RECORDING METHOD AND INFORMATION RECORDING/REPRODUCTION SYSTEM

(57) Abstract

An information recording medium including a plurality of sectors of the present invention includes: a first spare area including a spare sector for replacing a defective sector among the plurality of sectors; a defect management information area for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be recorded. The volume space is configured so that a second spare area including a spare sector for replacing a defective sector among the plurality of sectors can be additionally allocated. Location information indicating a location of the second spare area is recorded in the defect management information area.



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## DESCRIPTION

INFORMATION RECORDING MEDIUM,  
INFORMATION RECORDING METHOD

5

AND

## INFORMATION RECORDING/REPRODUCTION SYSTEM

## TECHNICAL FIELD

10 The present invention relates to an information recording medium, an information recording method and an information recording/reproduction system, in which it is possible to increase the reliability of data recording by dynamically extending the spare area according to the frequency of occurrence of defective sectors.

15

## BACKGROUND ART

20 An optical disk is a type of information recording medium which has a sector structure. In recent years, as the recording density and the capacity of an optical disk have been increased, it has become more important to ensure the reliability thereof.

25 Conventionally, a defect management method is known in the art for managing defective sectors on the optical disk (i.e., sectors which cannot be used for recording/reproduction of data). A spare area is provided in advance on the optical disk. When there is a defective sector on the optical disk, the defective sector is replaced by another sector in the spare area. Thus, the reliability of the optical disk is ensured. Such a defect management method is described in International Standards Organization ISO/IEC 10090 for 90 mm optical disks.

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The conventional defect management method described in the International Standards Organization ISO/IEC 10090 for 90 mm optical disks will now be outlined with reference to Figures 12 and 13.

5

Figure 12 illustrates a structure of a data recording area 800 of a conventional optical disk.

10 The data recording area 800 includes a plurality of sectors. Each of the plurality of sectors is assigned a physical sector number (hereinafter, referred to as a "PSN").

15 The data recording area 800 includes a defect management information area 801, a spare area 802 and a volume space 800a. The volume space 800a is arranged immediately after the spare area 802, and is defined as an area in which user data can be recorded. Each of the sectors included in the volume space 800a is assigned a logical  
20 sector number (hereinafter, abbreviated as an "LSN").

The size of the spare area 802 is predetermined. In order to change the size of the spare area 802, it is necessary to change the data structure of the replacement  
25 information stored in the defect management information area 801 by using a special command with physical format utility software. This operation will hereinafter be referred to as an initialization operation.

30 Figure 13 illustrates a procedure of a conventional format operation and a conventional data write operation. These operations are performed by a system control apparatus and an optical disk drive apparatus. The optical disk drive

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apparatus is connected to the system control apparatus. The system control apparatus is, for example, a computer system.

5 The format operation includes steps S901-S903 illustrated in Figure 13. The data write operation includes steps S904-S911. In Figure 12, each reference numeral that starts with "S" beside an arrow denotes a recording operation corresponding to a step illustrated in Figure 13.

10

When an optical disk is inserted into the optical disk drive apparatus, the optical disk drive apparatus reads out the defect management information area 801 and recognizes replacement information which indicates that a defective sector has been replaced by a spare sector (step S901).

15

The system control apparatus performs a FAT/root directory creation operation, issues a Write command and transmits data to the optical disk drive apparatus (step S902).

20

25 The optical disk drive apparatus uses format utility software to recognize the physical structure of the optical disk and records the data transmitted from the system control apparatus from the beginning of the volume space 800a (step S903). As a result, a FAT area 803 and a root directory area 804 are arranged starting from the beginning of the volume space 800a. Such a logical format operation is similar to the format operation for a file system in a MS-DOS format. As a result, the area from immediately after the root directory area 804 to the end of the optical disk is handled as a file data space 800b which is managed by

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the FAT.

A data write operation for recording data (File-a) under the root directory will now be described.

5

The system control apparatus performs a recording operation for the data (File-a), issues a Write command and transmits data to the optical disk drive apparatus (step S904). The location at which the data should be recorded is specified by an LSN.

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The optical disk drive apparatus records the data transmitted from the system control apparatus in a sector which is assigned the specified LSN (step S905). Whether or not the data has been correctly recorded is determined by reading out the recorded data and by comparing the read data with the transmitted data. When the data has not been correctly recorded, the sector which is assigned the specified LSN is detected as a defective sector. The defective sector occurs mainly due to dirt or dust attached to the optical disk.

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For example, assume a case where sector b (sector 814) illustrated in Figure 12 has been detected as a defective sector. In such a case, the optical disk drive apparatus records the data which is supposed to be recorded in the defective sector 814 in #1 spare sector 810 of the spare area 802, generates, as defect management information, #1 replacement entry 832 which indicates that the defective sector 814 has been replaced by the #1 spare sector 810, and records the #1 replacement entry 832 in the defect management information area 801 (step S906).

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- 5 -

The #1 replacement entry 832 includes location information 833 indicating the location of the defective sector and location information 834 indicating the location of the spare sector by which it is replaced. Each of the  
5 location information 833 and 834 is represented by a PSN.

When the system control apparatus instructs the optical disk drive apparatus to read out data from the defective sector 814, the optical disk drive apparatus  
10 performs address conversion with reference to the #1 replacement entry 832 and reads out the data from the #1 spare sector 810.

Thus, by replacing a defective sector by a spare  
15 sector, it is possible to ensure the reliability of the optical disk. Moreover, since such defective sector replacement operation is performed by the optical disk drive apparatus, it is possible to ensure that the system control apparatus always records data at a location corresponding  
20 to the specified LSN. As a result, the system control apparatus can handle the optical disk as a defect-free medium.

Then, the system control apparatus performs a root  
25 directory recording operation, issues a Write command and transmits data to the optical disk drive apparatus (step S907).

The optical disk drive apparatus updates root  
30 directory information recorded in the root directory area 804 according to the data transmitted from the system control apparatus (step S908).

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The system control apparatus performs a FAT recording operation, issues a Write command and transmits data to the optical disk drive apparatus (step S909).

5           The optical disk drive apparatus updates FAT information recorded in the FAT area 803 according to the data transmitted from the system control apparatus (step S910). Thus, the data (File-a) is registered under the root directory.

10           The optical disk drive apparatus records the updated defect management information in the defect management information area 801. Such recording is performed when there is no data recording instruction from the system  
15 control apparatus for a few seconds.

In the above-described conventional defect management method, the size of a spare area is fixed. Therefore, if there occurs defective sectors beyond the size  
20 of the replacement area, data cannot be recorded on the optical disk even when an unallocated area available for recording still exists on the optical disk. In order to record data on the optical disk, it is necessary to change the size of the spare area by performing another  
25 initialization operation on the optical disk. In such a case, data recorded in the volume space needed to be backed up on another medium before performing the initialization operation because the LSN allocation would be changed over the entire area of the volume space.

30           Especially, in a case where an optical disk is used with consumer equipment, the user may handle the optical disk while eating food or a child may inadvertently touch



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the surface of the optical disk, whereby more defective sectors may occur on the optical disk than expected by the manufacturer.

5 DISCLOSURE OF THE INVENTION

According to one aspect of this invention, an information recording medium including a plurality of sectors includes: a first spare area including a spare sector for replacing a defective sector among the plurality of  
10 sectors; a defect management information area for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be recorded. The volume space is configured so that a second spare area including a spare sector for replacing a defective sector  
15 among the plurality of sectors can be additionally allocated. Location information indicating a location of the second spare area is recorded in the defect management information area.

20 In one embodiment of the invention, the second spare area is allocated in an area separated from the first spare area.

In one embodiment of the invention, the second spare  
25 area is allocated in an area contiguous with the first spare area.

In one embodiment of the invention, each of the first spare area and the second spare area is assigned physical  
30 sector numbers. The physical sector numbers assigned to the first spare area are smaller than the physical sector numbers assigned to the second spare area.

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In one embodiment of the invention, the second spare area includes a plurality of spare sectors. Each of the plurality of spare sectors is assigned a physical sector number. The defective sector is replaced by one of the  
5 plurality of spare sectors in descending order of the physical sector numbers respectively assigned to the plurality of spare sectors.

In one embodiment of the invention, the second spare  
10 area can be extended in a direction along which the physical sector number decreases.

In one embodiment of the invention, the second spare area is allocated outside the volume space.  
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In one embodiment of the invention, the second spare area is allocated inside the volume space. The location information indicating the location of the second spare area is recorded in a basic file structure management area for  
20 managing a basic file structure.

According to another aspect of this invention, an information recording medium including a plurality of sectors includes: a first spare area including a spare sector  
25 for replacing a defective sector among the plurality of sectors; a defect management information area for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be recorded. The volume space is configured so that a second spare area  
30 including a spare sector for replacing a defective sector among the plurality of sectors can be additionally allocated. Information indicating an amount of spare area available in the first spare area and information indicating an amount

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of spare area available in the second spare area are recorded in the defect management information area.

5 In one embodiment of the invention, the information of the amount of spare area available in the first spare area includes a replacement entry which indicates that the defective sector has been replaced by a spare sector in the first spare area. The information of the amount of spare area available in the second spare area includes a size of  
10 the second spare area and a replacement entry which indicates that the defective sector has been replaced by a spare sector in the second spare area.

15 In one embodiment of the invention, the information of the amount of spare area available in the first spare area includes a first full flag which indicates whether or not there is any spare sector available in the first spare area. The information of the amount of spare area available in the second spare area includes a second full flag which  
20 indicates whether or not there is any spare sector available in the second spare area.

According to still another aspect of this invention, there is provided an information recording method for  
25 recording information on an information recording medium including a plurality of sectors. The information recording medium includes: a first spare area including a spare sector for replacing a defective sector among the plurality of sectors; a defect management information area  
30 for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be recorded, wherein the volume space is configured so that a second spare area including a spare sector for replacing

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a defective sector among the plurality of sectors can be additionally allocated. The information recording method includes the steps of: (a) obtaining information which indicates a status of consumption of the first spare area;  
5 (b) determining whether or not to additionally allocate the second spare area according to the information which indicates the status of consumption of the first spare area;  
(c) when it is determined to additionally allocate the second spare area, making a part of the volume space  
10 available as the second spare area; and (d) recording information indicating a location of the second spare area in the defect management information area.

In one embodiment of the invention, a first full flag  
15 which indicates whether or not there is any spare sector available in the first spare area is recorded in the defect management information area. The step (a) includes the step of determining whether or not there is any spare sector available in the first spare area by referencing the first  
20 full flag.

In one embodiment of the invention, a replacement entry which indicates that the defective sector has been replaced by a spare sector in the first spare area is recorded  
25 in the defect management information area. The step (a) includes the step of determining whether or not there is any spare sector available in the first spare area by referencing the replacement entry.

30 In one embodiment of the invention, the step (c) includes the steps of: (c-1) reducing the volume space; and (c-2) allocating an area on an outer periphery side following the reduced volume space as the second spare area.

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In one embodiment of the invention, the step (c) includes the step of allocating a part of a logical volume space of the volume space as the second spare area.

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In one embodiment of the invention, the step (c) includes the step of moving data recorded in a part of a logical volume space of the volume space to another part of the logical volume space, and then allocating the part of the logical volume space as the second spare area.

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In one embodiment of the invention, the step (d) includes the step of, before recording the information indicating the location of the second spare area in the defect management information area, detecting a defective sector in the part of the volume space made available.

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In one embodiment of the invention, the second spare area is allocated in an area separated from the first spare area.

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In one embodiment of the invention, the second spare area is allocated in an area contiguous with the first spare area.

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In one embodiment of the invention, each of the first spare area and the second spare area is assigned physical sector numbers. The physical sector numbers assigned to the first spare area are smaller than the physical sector numbers assigned to the second spare area.

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In one embodiment of the invention, the second spare area includes a plurality of spare sectors. Each of the

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plurality of spare sectors is assigned a physical sector number. The defective sector is replaced by one of the plurality of spare sectors in descending order of the physical sector numbers respectively assigned to the  
5 plurality of spare sectors.

In one embodiment of the invention, the second spare area can be extended in a direction along which the physical sector number decreases.

10

According to still another aspect of this invention, there is provided an information recording method for recording information on an information recording medium including a plurality of sectors. The information  
15 recording medium includes: a first spare area including a spare sector for replacing a defective sector among the plurality of sectors; a defect management information area for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be  
20 recorded, wherein the volume space is configured so that a second spare area including a spare sector for replacing a defective sector among the plurality of sectors can be additionally allocated. The information recording method includes the steps of: (a) obtaining information which  
25 indicates a status of consumption of the second spare area; (b) determining whether or not to additionally allocate the second spare area according to the information which indicates the status of consumption of the second spare area; (c) when it is determined to additionally allocate the  
30 second spare area, making a part of the volume space available as the second spare area; and (d) recording information indicating a location of the second spare area in the defect management information area.

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In one embodiment of the invention, a second full flag which indicates whether or not there is any spare sector available in the second spare area is recorded in the defect management information area. The step (a) includes the step of determining whether or not there is any spare sector available in the second spare area by referencing the second full flag.

In one embodiment of the invention, a replacement entry which indicates that the defective sector has been replaced by a spare sector in the second spare area is recorded in the defect management information area. The step (a) includes the step of determining whether or not there is any spare sector available in the second spare area by referencing the replacement entry.

In one embodiment of the invention, the step (c) includes the steps of: (c-1) reducing the volume space; and (c-2) allocating an area on an outer periphery side following the reduced volume space as the second spare area.

In one embodiment of the invention, the step (c) includes the step of allocating a part of a logical volume space of the volume space as the second spare area.

In one embodiment of the invention, the step (c) includes the step of moving data recorded in a part of a logical volume space of the volume space to another part of the logical volume space, and then allocating the part of the logical volume space as the second spare area.

In one embodiment of the invention, the step (d)

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includes the step of, before recording the information indicating the location of the second spare area in the defect management information area, detecting a defective sector in the part of the volume space made available.

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In one embodiment of the invention, the step (d) includes the step of resetting a second full flag which indicates whether or not there is any spare sector available in the second spare area, after recording the information  
10 indicating the location of the second spare area in the defect management information area.

In one embodiment of the invention, the second spare area is allocated in an area separated from the first spare  
15 area.

In one embodiment of the invention, the second spare area is allocated in an area contiguous with the first spare  
20 area.

In one embodiment of the invention, each of the first spare area and the second spare area is assigned physical sector numbers. The physical sector numbers assigned to the first spare area are smaller than the physical sector numbers  
25 assigned to the second spare area.

In one embodiment of the invention, the second spare area includes a plurality of spare sectors. Each of the plurality of spare sectors is assigned a physical sector  
30 number. The defective sector is replaced by one of the plurality of spare sectors in descending order of the physical sector numbers respectively assigned to the plurality of spare sectors.



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In one embodiment of the invention, the second spare area can be extended in a direction along which the physical sector number decreases.

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According to still another aspect of this invention, there is provided an information recording/reproduction system for an information recording medium including a plurality of sectors. The information recording medium includes: a first spare area including a spare sector for replacing a defective sector among the plurality of sectors; a defect management information area for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be recorded, wherein the volume space is configured so that a second spare area including a spare sector for replacing a defective sector among the plurality of sectors can be additionally allocated. The information recording/reproduction system includes: a remaining spare area amount detection section for obtaining information indicating a status of consumption of the first spare area; a spare area extension determination section for determining whether or not to additionally allocate the second spare area according to the information indicating the status of consumption of the first spare area; a spare extension area allocation section for, when it is determined to additionally allocate the second spare area, making a part of the volume space available as the second spare area; and a spare area allocation section for recording location information indicating a location of the second spare area in the defect management information area.

In one embodiment of the invention, a first full flag which indicates whether or not there is any spare sector

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available in the first spare area is recorded in the defect management information area. The remaining spare area amount detection section determines whether or not there is any spare sector available in the first spare area by  
5 referencing the first full flag.

In one embodiment of the invention, a replacement entry which indicates that the defective sector has been replaced by a spare sector in the first spare area is recorded  
10 in the defect management information area. The remaining spare area amount detection section determines whether or not there is any spare sector available in the first spare area by referencing the replacement entry.

15 In one embodiment of the invention, the spare extension area allocation section reduces the volume space, and allocates an area on an outer periphery side following the reduced volume space as the second spare area.

20 In one embodiment of the invention, the spare extension area allocation section allocates a part of a logical volume space of the volume space as the second spare area.

25 In one embodiment of the invention, the spare extension area allocation section moves data recorded in a part of a logical volume space of the volume space to another part of the logical volume space, and then allocates the part of the logical volume space as the second spare area.

30 In one embodiment of the invention, the second spare area is allocated in an area separated from the first spare area.

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In one embodiment of the invention, the second spare area is allocated in an area contiguous with the first spare area.

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In one embodiment of the invention, each of the first spare area and the second spare area is assigned physical sector numbers. The physical sector numbers assigned to the first spare area are smaller than the physical sector numbers assigned to the second spare area.

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In one embodiment of the invention, the second spare area includes a plurality of spare sectors. Each of the plurality of spare sectors is assigned a physical sector number. The defective sector is replaced by one of the plurality of spare sectors in descending order of the physical sector numbers respectively assigned to the plurality of spare sectors.

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In one embodiment of the invention, the second spare area can be extended in a direction along which the physical sector number decreases.

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In one embodiment of the invention, the information recording/reproduction system includes a recording apparatus for recording information on the information recording medium and a control apparatus for controlling the recording apparatus. The recording apparatus includes a remaining spare amount reporting section for reporting to the control apparatus information indicating a status of consumption of the first spare area which is obtained from the remaining spare area amount detection section.

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In one embodiment of the invention, the information indicating the status of consumption of the first spare area includes information indicating a remaining amount of the first spare area.

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In one embodiment of the invention, the information indicating the status of consumption of the first spare area includes information indicating an error status in response to a data recording instruction.

10

According to still another aspect of this invention, there is provided an information recording/reproduction system for an information recording medium including a plurality of sectors. The information recording medium includes: a first spare area including a spare sector for replacing a defective sector among the plurality of sectors; a defect management information area for managing the replacement of the defective sector by the spare sector; and a volume space in which user data can be recorded, wherein the volume space is configured so that a second spare area including a spare sector for replacing a defective sector among the plurality of sectors can be additionally allocated. The information recording/reproduction system includes: a remaining spare area amount detection section for obtaining information indicating a status of consumption of the second spare area; a spare area extension determination section for determining whether or not to additionally allocate the second spare area according to the information indicating the status of consumption of the second spare area; a spare extension area allocation section for, when it is determined to additionally allocate the second spare area, making a part of the volume space available as the second spare area; and a spare area allocation section for recording location

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information indicating a location of the second spare area in the defect management information area.

5        In one embodiment of the invention, a second full flag which indicates whether or not there is any spare sector available in the second spare area is recorded in the defect management information area. The remaining spare area amount detection section determines whether or not there is any spare sector available in the second spare area by  
10        referencing the second full flag.

15        In one embodiment of the invention, a replacement entry which indicates that the defective sector has been replaced by a spare sector in the second spare area is recorded in the defect management information area. The remaining spare area amount detection section determines whether or not there is any spare sector available in the second spare area by referencing the replacement entry.

20        In one embodiment of the invention, the spare extension area allocation section reduces the volume space, and allocates an area on an outer periphery side following the reduced volume space as the second spare area.

25        In one embodiment of the invention, the spare extension area allocation section allocates a part of a logical volume space of the volume space as the second spare area.

30        In one embodiment of the invention, the spare extension area allocation section moves data recorded in a part of a logical volume space of the volume space to another part of the logical volume space, and then allocates the

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part of the logical volume space as the second spare area.

5           In one embodiment of the invention, the spare extension area allocation section resets a second full flag which indicates whether or not there is any spare sector available in the second spare area, after recording the information indicating the location of the second spare area in the defect management information area.

10           In one embodiment of the invention, the second spare area is allocated in an area separated from the first spare area.

15           In one embodiment of the invention, the second spare area is allocated in an area contiguous with the first spare area.

20           In one embodiment of the invention, each of the first spare area and the second spare area is assigned physical sector numbers. The physical sector numbers assigned to the first spare area are smaller than the physical sector numbers assigned to the second spare area.

25           In one embodiment of the invention, the second spare area includes a plurality of spare sectors; each of the plurality of spare sectors is assigned a physical sector number; and the defective sector is replaced by one of the plurality of spare sectors in descending order of the physical sector numbers respectively assigned to the  
30           plurality of spare sectors.

          In one embodiment of the invention, the second spare area can be extended in a direction along which the physical

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sector number decreases.

In one embodiment of the invention, the information recording/reproduction system includes a recording apparatus for recording information on the information recording medium and a control apparatus for controlling the recording apparatus. The recording apparatus includes a remaining spare amount reporting section for reporting to the control apparatus information indicating a status of consumption of the second spare area which is obtained from the remaining spare area amount detection section.

In one embodiment of the invention, the information indicating the status of consumption of the second spare area includes information indicating a remaining amount of the second spare area.

In one embodiment of the invention, the information indicating the status of consumption of the second spare area includes information indicating an error status in response to a data recording instruction.

Thus, the invention described herein makes possible the advantage of providing an information recording medium, an information recording method and an information recording/reproduction system, in which it is possible to increase the reliability of data recording by dynamically extending the spare area according to the frequency of occurrence of defective sectors.

This and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with

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reference to the accompanying figures.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5        Figure 1 is a diagram illustrating a structure of  
a data recording area 100 of an optical disk according to  
an embodiment of the present invention;

10       Figure 2 is a block diagram illustrating a structure  
of an information recording/reproduction system 1a  
according to an embodiment of the present invention;

Figure 3 is a protocol chart illustrating a  
procedure of a format operation;

15       Figure 4 is a diagram illustrating a structure of  
the data recording area 100 of an optical disk after a format  
operation;

20       Figure 5 is a protocol chart illustrating a  
procedure of a data write operation;

25       Figures 6A-6C are protocol charts illustrating an  
procedure of an operation of determining whether or not it  
is necessary to extend a first spare area 102;

Figure 7 is a protocol chart illustrating a  
procedure of an operation of extending the first spare  
area 102 and a second spare area 108;

30       Figure 8 is a diagram illustrating a structure of  
the data recording area 100 of an optical disk according  
to an embodiment of the present invention;



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Figure 9 is a protocol chart illustrating a procedure of a data write operation for recording a file on an optical disk;

5           Figure 10 is a protocol chart illustrating a procedure of an operation which is performed when an optical disk is inserted into an optical disk drive apparatus;

10           Figure 11 is a diagram illustrating an operation of updating volume structure areas 103 and 109 and a basic file structure area 104;

15           Figure 12 is a diagram illustrating a structure of a data recording area 800 of a conventional optical disk; and

20           Figure 13 is a protocol chart illustrating a procedure of a conventional format operation and a conventional data write operation.

#### BEST MODE FOR CARRYING OUT THE INVENTION

25           An information recording medium of the present invention includes a first spare area including a spare sector for replacing a defective sector, a defect management information area for managing replacement of a defective sector by a spare sector, and a volume space in which user data can be recorded.

30           The volume space is configured so that a second spare area including a spare sector for replacing a defective sector can be additionally allocated. When all of the spare sectors provided in advance in the first spare area have been consumed by the defective sector replacement operation,

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a part of the volume space is made available as a second spare area. Thus, by additionally allocating the second spare area when necessary, it is possible to ensure the defect-free property of the optical disk even when there  
5 occurs more defective sectors than expected by the manufacturer of the optical disk.

Location information indicating the location of the second spare area is recorded in the defect management  
10 information area.

Embodiments of the present invention will now be described with reference to the drawings.

15 Embodiment 1 is an embodiment in which the second spare area is allocated inside the volume space by updating the file structure. Embodiment 2 is an embodiment in which the second spare area is allocated outside the volume space by updating the volume structure and the file structure.

20

(Embodiment 1)

Figure 2 illustrates a structure of an information recording/reproduction system 1a according to an embodiment of the present invention. The information recording/reproduction system 1a records information on the  
25 information recording medium and reproduces information recorded on the information recording medium. The information recording medium may be any type of rewritable optical disk such as a DVD-RAM.

30

It is assumed in the following description that the information recording medium is a rewritable optical disk on/from which files managed by a file structure defined in

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the ECMA167 standard can be recorded/reproduced by sectors. Hereinafter, such a rewritable optical disk will be referred to simply as an optical disk.

5           As illustrated in Figure 2, the information recording/reproduction system 1a includes a system control apparatus 200 and an optical disk drive apparatus 204. The system control apparatus 200 and the optical disk drive apparatus 204 are connected to each other via an I/O bus 203.

10           The system control apparatus 200 includes a system control section 201 for processing file structure information and a memory circuit 202. The system control section 201 may be implemented by, for example, a  
15           microprocessor including a control program and a memory for storing operation results.

          The system control section 201 includes: a file structure operation section 211 for performing a bit map  
20           operation for managing unallocated areas in a logical volume space; a spare extension area detection section 212 for examining whether or not an area which is determined to be allocated as an additional spare area has already been used;  
          a file moving operation section 213 for allocating an  
25           additional spare area by moving a file recorded in the area which is determined to be allocated as an additional spare area to another area; a spare extension area allocation section 214 for registering an additional spare area in a file structure; a spare area extension determination  
30           section 215 for determining whether or not the spare area should be extended based on the amount of spare area remaining; a command status operation section 216 for recognizing whether or not a defective sector has been

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detected during data recording by the execution result of a Write command; and a spare extension area issue section 217 for directing a spare area to be extended for the optical disk drive apparatus 204 for updating the defect management information.

The memory circuit 202 includes a file structure memory 221, a bit map memory 222, a data memory 223, and a spare area information memory 224 for storing information indicating the amount of spare area remaining and information indicating the location of the spare area.

The optical disk drive apparatus 204 includes a drive control section 205 for performing a defect management operation and controlling the recording/reproduction of data on/from the optical disk, and a memory circuit 206. The drive control section 205 may be implemented by, for example, a microprocessor including a control program and a memory for arithmetic operations.

The drive control section 205 includes: a remaining spare amount reporting section 231 for reporting the area size which can be replaced by the spare area; a spare area allocation section 232 for updating defect management information according to a spare area extension command from the system control apparatus 200; a remaining spare area amount detection section 233 for detecting the area which can be replaced by the spare area based on a replacement entry of the defect management information area; a defective sector operation section 234 for allocating a defective sector detected during data recording by a spare sector of the spare area and recording data in the spare sector; a data write control section 235 for controlling recording

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of data to the optical disk; and a data read control section 236 for controlling reproduction of data from the optical disk.

5           The memory circuit 206 includes a defect management information memory 241 for storing the defect management information, and a data memory 242.

10           A format operation performed on an optical disk according to the present invention will now be described with reference to Figures 1, 2, 3 and 4.

15           Figure 4 illustrates a structure of the data recording area 100 of an optical disk after the format operation.

            The data recording area 100 includes a plurality of sectors. Each of the plurality of sectors is assigned a PSN.

20           The data recording area 100 includes a defect management information area 101, a first spare area 102 and a volume space 100a.

25           Defect management information 130 is recorded in the defect management information area 101. The defect management information 130 includes an SDL descriptor 131 for identifying SDL information, a spare area full flag 132, location information 133 indicating the location of the second spare area 108, and #1 replacement entry 134  
30           indicating that a defective sector has been replaced by a spare sector.

            The spare area full flag 132 includes a first full

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flag 138 for the first spare area 102 and a second full flag 139 for the second spare area 108. The first full flag 138 indicates whether or not there is any spare sector available in the first spare area 102. The second full  
5 flag 139, when it is reset, indicates that there is a spare sector available in the second spare area 108. The second full flag 139, when it is set, indicates that there is no more spare sector available in the second spare area 108 or that no second spare area 108 has been allocated.

10

Hereinafter, the location information 133 indicating the location of the second spare area 108 will be referred to simply as the "second spare area location information 133". The second spare area location  
15 information 133 is represented by, for example, the PSN of the first sector included in the second spare area 108 and the PSN of the last sector included in the second spare area 108.

20

In the example illustrated in Figure 4, the second spare area has not yet been allocated on the data recording area 100. In such a case, the second spare area location information 133 has a value (e.g., the NULL value) which indicates that "the second spare area has not yet been  
25 allocated on the data recording area 100".

In the example illustrated in Figure 4, the number of replacement entries included in the defect management information 130 is 1. The defect management information 130  
30 may include a number of replacement entries equal to the number of spare sectors replacing defective sectors. Therefore, when the number of spare sectors replacing defective sectors is N, the defect management informa-

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tion 130 may include #1-#N replacement entries. Herein, N is any integer. Each of the #1-#N replacement entries includes location information 136 indicating the location of the defective sector and location information 137  
5 indicating the location of the spare sector replacing the defective sector. Each of the location information 136 and 137 is represented by, for example, a PSN.

The size of the first spare area 102 is fixed. In  
10 the example illustrated in Figure 4, the first spare area 102 includes three spare sectors 110-112, i.e., #1 spare sector to #3 spare sector. Each of the spare sectors 110-112 is used to replace a defective sector. The number of spare sectors included in the first spare area 102  
15 is not limited to 3. The first spare area 102 may include any number of spare sectors.

The volume space 100a is arranged immediately after the first spare area 102, and is defined as an area in which  
20 user data can be recorded. Each of the sectors included in the volume space 100a is assigned a logical sector number. The volume space 100a includes the volume structure area 103, a logical volume space 100b and the volume structure area 109.

25  
Figure 3 illustrates a procedure of a format operation. The format operation is performed by the system control apparatus 200 and the optical disk drive apparatus 204.

30  
The format operation includes steps S301-S307 illustrated in Figure 3. In Figure 4, each reference numeral that starts with "S" beside an arrow denotes a

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recording operation corresponding to a step illustrated in Figure 3.

5       When the optical disk is inserted into the optical disk drive apparatus 204, the defect management information 130 is read out from the defect management information area 101. The defect management information 130 is stored in the defect management information memory 241.

10       The defect management information 130 stored in the defect management information memory 241 is referenced by the remaining spare amount reporting section 231 and the remaining spare area amount detection section 233, as will be described below.

15       The remaining spare area amount detection section 233 recognizes the location information of the first and second spare areas and the status of consumption of the first and second spare areas (step S301). The status of  
20       consumption of each spare area is recognized by, for example, retrieving one of the replacement entries recorded in the defect management information area 101 that has the smallest address information (e.g., the physical sector number) of a spare sector.

25       The file structure operation section 211 issues a Get Spare Info command to the optical disk drive apparatus 204 in order to inquire as to the spare area information (step S302).

30       The remaining spare amount reporting section 231 reports the spare area information to the system control apparatus 200 based on the defect management informa-



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tion 130 stored in the defect management information memory 241 (step S303). The spare area information includes the location information 133 indicating the location of the second spare area. The spare area  
5 information is stored in the spare area information memory 224.

The file structure operation section 211 performs a volume structure/basic file structure creation operation  
10 and issues a Write command and transmits data to the optical disk drive apparatus 204 (step S304). The data is once stored in the file structure memory 221, and then transferred from the file structure memory 221 to the data memory 242.

15 The data write control section 235 records data stored in the data memory 242 starting from the beginning of the volume space 100a (i.e., the sector assigned the LSN "0") (step S305). As a result, the volume structure  
20 area 103 and the basic file structure area 104 are allocated starting from the beginning of the volume space 100a.

Although not shown in Figure 4, an anchor volume descriptor pointer, a volume descriptor sequence, a file  
25 set descriptor, a file entry for the system stream directory and the system stream directory are recorded in the volume structure area 103.

The basic file structure area 104 includes a space  
30 bit map area 113, a file entry area 114, a root directory area 115 and a file entry area 116.

A space bit map is recorded in the space bit map

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area 113. The space bit map is a string of bits which indicates the allocation status in each sector of the logical volume space 100b. By referencing the space bit map, it is possible to examine the status of consumption of each sector  
5 in the logical volume space 100b.

The location information and management information for the root directory area 115 are recorded in the file entry area 114.  
10

The names of the files recorded under the root directory and the location information for the file entry of each of such files are recorded in the root directory area 115.  
15

A file entry specified by the system stream directory is recorded in the file entry area 116. The location information of the stream of the second spare area to be registered in the system stream directory is managed  
20 by this file entry. The file entry includes a descriptor tag 141 for identifying the file entry, a file attribute 142 and location information 143 indicating the location of the second spare area 108.

Hereinafter, the location information 143 indicating the location of the second spare area 108 will be referred to simply as the "second spare area location information 143". The second spare area location information 143 is represented by, for example, the LSN of  
25 the first sector included in the second spare area 108 and  
30 the size of the second spare area 108.

In the format operation, information equivalent to

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the second spare area location information 133 included in the defect management information 130 is recorded in the file entry area 116 as the second spare area location information 143. In the example illustrated in Figure 4,  
5 the second spare area location information 133 has the NULL value, as discussed above. Accordingly, the second spare area location information 143 also has the NULL value.

Whether or not the data transmitted from the system  
10 control apparatus 200 has been correctly recorded in the volume structure area 103 and the basic file structure area 104 is determined by reading out the recorded data and by comparing the read data with the transmitted data (i.e., the data stored in the data memory 242). Such a  
15 determination is performed by the defective sector operation section 234.

For example, when the data transmitted from the system control apparatus 200 is not correctly recorded in  
20 the root directory area 115, the root directory area 115 is detected as a defective sector. In such a case, the defective sector operation section 234 replaces the root directory area 115 by one of the available spare sectors included in the first spare area 102 that has the largest  
25 address (i.e., the #1 spare sector 112). As a result, data which is supposed to be recorded in the root directory area 115 is recorded in the #1 spare sector 112 of the first spare area 102. Moreover, the defective sector operation section 234 generates the #1 replacement entry 134 which  
30 indicates that the root directory area 115 has been replaced by the #1 spare sector 112 and stores the #1 replacement entry 134 in the defect management information memory 241 (step S306).

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The defective sector operation section 234 records the updated defect management information 130 stored in the defect management information memory 241 in the defect management information area 101 (step S307). Such recording is performed immediately after step S306 or when there is no command to record the data from the system control apparatus 200 for a predetermined period of time (e.g., 5 seconds).

10

As described above, in the optical disk format operation, information that has consistency with the second spare area location information 133 recorded in the defect management information area 101 is recorded in the basic file structure area 104 as the second spare area location information 143. By performing the above-described format operation on a used optical disk, it is possible to reuse the used optical disk. This is because even if all of the information in the volume space 100a is erased, the information in the second spare area is stored in the defect management information area 101.

15  
20

The second spare area location information 143 is managed by the system control apparatus 200, and the second spare area location information 133 is managed by the optical disk drive apparatus 204. It is necessary to ensure that the location information 143 and 133 always have consistency with each other. Countermeasures which can be taken when the information 143 and 133 are not consistent with each other and a method for recovering the inconsistency between the information 143 and 133 will be described later.

25  
30

A data write operation of recording a file named

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"File-a" under the root directory of a formatted optical disk will now be described with reference to Figures 1, 2 and 5.

5               Figure 1 illustrates a structure of the data recording area 100 of the optical disk after the data write operation.

10              Figure 5 illustrates a procedure of the data write operation. The data write operation is performed by the system control apparatus 200 and the optical disk drive apparatus 204.

15              The data write operation includes steps S401-S417 illustrated in Figure 5. In Figure 1, each reference numeral that starts with "S" beside an arrow denotes a recording operation corresponding to a step illustrated in Figure 5.

20              When the optical disk is inserted into the optical disk drive apparatus 204, the same defect management information operation as that done in the format operation is performed as a start-up operation for the optical disk drive apparatus 204 (step S401).

25              The file structure operation section 211 issues a Read command to the optical disk drive apparatus 204 as a start-up operation for the system control apparatus 200 (step S402).

30              The data read control section 236 reproduces data from the volume structure area 103 and the basic file structure area 104 according to the address specified by

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the Read command and transmits the reproduced data to the file structure memory 221 (step S403).

5       The file structure operation section 211 analyzes  
the volume structure and the basic file structure based on  
the data transmitted to the file structure memory 221. As  
a result, the file structure operation section 211  
recognizes the logical volume space 100a based on the data  
reproduced from the volume structure area 103, recognizes  
10   the location and the size of an unallocated area 107 based  
on the data reproduced from the space bit map area 113,  
recognizes the directory structure based on the data  
reproduced from the root directory area 115, and recognizes  
the second spare area location information 143 based on the  
15   data reproduced from the file entry area 116 (step S402).

      The file structure operation section 211 creates  
data of a file named "File-a" and stores the data in the  
data memory 223. Moreover, the file structure operation  
20   section 211 creates data of a file entry and stores the data  
in the file structure memory 221. The file structure  
operation section 211 issues a Write command and each data  
to the optical disk drive apparatus 204 (step S404). The  
Write command is used to record each data at the address  
25   of the unallocated area 107 recognized in step S402.

      The data stored in the data memory 223 and the data  
stored in the file structure memory 221 are transmitted to  
the data memory 242. The data write control section 235  
30   records the respective data transmitted in the data mem-  
ory 242 in a data area 105 and in a file structure area 106  
according to the addresses specified by the Write command  
(step S405).

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The defective sector operation section 234 performs a replacement operation by the same method as that described in the description of the format operation. For example, assume a case where sector b (sector 118) illustrated in Figure 1 has been detected as a defective sector. In such a case, the defective sector operation section 234 records the data, which is supposed to be recorded in the defective sector 118, in #2 spare sector 111 of the first spare area 102, generates #2 replacement entry 135 which indicates that the defective sector 118 has been replaced by the #2 spare sector 111, and records the #2 replacement entry 135 in the defect management information memory 241 (step S406).

In order to register the file (File-a) under the root directory, it is necessary to update the data recorded in the root directory area 115. The file structure operation section 211 issues the Write command and transmits the data to the optical disk drive apparatus 204 (step S407).

The data write control section 235 references the #1 replacement entry 134, converts the address of the root directory area 115 specified by the Write command to the address of the #1 spare sector 112, and records the data transmitted from the system control apparatus 200 in the #1 spare sector 112 (step S408).

The spare area extension determination section 215 determines, based on the status of consumption of the first spare area 102, whether or not it is necessary to extend the first spare area 102. There are various methods for such a determination. The details of such various methods will

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later be described with reference to Figures 6A-6C.

Herein, an example of such determination methods will be described. For example, the spare area extension  
5 determination section 215 issues a Get Event Status Notification command to the optical disk drive apparatus 204. This command is used to inquire as to the status of consumption of the first spare area 102. In response to this inquiry, the spare area extension determination section 215  
10 determines that it is necessary to extend the first spare area 102 when the optical disk drive apparatus 204 reports shortage information which indicates that the remaining amount of the first spare area 102 is less than a predetermined size (e.g., 1 MB) (step S409).

15 In response to the command issued from the system control apparatus 200 in step S409, the remaining spare area amount detection section 233 calculates the remaining amount of the first spare area 102 (e.g., the number of spare  
20 sectors in the first spare area 102 that are available for replacement) based on the information of the replacement entry stored in the defect management information memory 241. If the remaining amount is less than the predetermined size, the remaining spare area amount detection section 233  
25 instructs the remaining spare amount reporting section 231 to report the shortage information to the system control apparatus 200. The remaining spare amount reporting section 231 reports the shortage information to the system control apparatus 200 (step S410).

30 In the example illustrated in Figure 1, the defective sector 118 is detected when recording data in the data area 105, and the #2 spare sector 111 is used to replace



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the defective sector 118. Therefore, the #3 spare sector 110 is the only spare sector in the first spare area 102 that is available for replacement. Then, if another defective sector occurs, the first spare area 102 would be exhausted, whereby no more replacement operation can be done. Therefore, the remaining spare amount reporting section 231 reports the shortage information to the system control apparatus 200.

10           In order to enlarge spare area, it is necessary to update the file entry area 116, the location information 133 indicating the location of the second spare area 108, and the space bit map area 113.

15           The system control apparatus 200 recognizes the unallocated area 107 based on the data reproduced from the space bit map area 113 and determines the area to be reserved as an additional spare area (i.e., the area where the second spare area 108 is allocated). The system control apparatus 200 updates the data stored in the file structure memory 221 in order to register the extended spare area, and updates the data stored in the bit map memory 222 so that the sectors of the area where the second spare area 108 is to be allocated are indicated as "allocated".

25           The system control apparatus 200 issues a Write command and transmits the data for the file entry area 116 stored in the file structure memory 221 to the optical disk drive apparatus 204 (step S411).

30           The optical disk drive apparatus 204 updates the file entry area 116 by recording the data transmitted from the system control apparatus 200 in the file entry area 116

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(step S412).

The system control apparatus 200 issues an Alloc Spare command and transmits the data for updating the second spare area location information 133 to the optical disk drive apparatus 204 (step S413).

The optical disk drive apparatus 204 updates the second spare area location information 133 stored in the defect management information memory 241 based on the data transmitted from the system control apparatus 200 (step S414).

Through the operations of steps S412 and S414, the second spare area 108 becomes available as an added spare area in the optical disk drive apparatus 204. In the example illustrated in Figure 1, the second spare area 108 includes #4 spare sector 122 to #6 spare sector 120. The number of spare sectors included in the second spare area 108 is not limited to 3. The second spare area 108 may include any number of spare sectors.

The file structure operation section 211 transmits the data for the space bit map area 113 stored in the file structure memory 221 to the optical disk drive apparatus 204 (step S415).

The data write control section 235 updates the space bit map area 113 by recording the data transmitted from the system control apparatus 200 in the space bit map area 113 (step S416).

The defective sector operation section 234 records

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in the defect management information area 101 the data which is stored in the defect management information memory 241 by the method described above in the procedure of the exemplary format operation (step S417).

5

As described above, in the data write operation for recording a file on the optical disk, it is possible to extend the first spare area 102 (i.e., to additionally allocate the second spare area 108) based on the status of consumption of the first spare area 102. Thus, it is possible to increase the reliability of data recording without performing an initialization operation.

When recording a file on the optical disk, the file structure operation section 211 may determine locations where data can be recorded, sequentially starting from a sector with the least LSN. In this way, data is recorded preferentially from the inner periphery of the optical disk, so that data is less likely to be recorded in an area to which the second spare area is extended, whereby it is possible to easily extend the spare area without moving files.

While an optical disk including the first spare area has been described in the above embodiment, the present invention may alternatively be applied to an optical disk in which the first spare area does not exist. For example, it is possible not to allocate the second spare area when there is no defective sector, while additionally allocating the second spare area when there occurs a defective sector. With such a defect management method, it is possible to obtain effects similar to those realized in the above-described embodiment.

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Next, a method for determining whether or not it is necessary to extend the first spare area 102 will be described with reference to Figures 1, 2 and 6A-6C. This method may alternatively be applied to a determination of whether or not it is necessary to extend the second spare area 108.

Figures 6A-6C are protocol charts illustrating an procedure of an operation of determining whether or not it is necessary to extend the first spare area 102. This operation is performed by the optical disk drive apparatus 204 and the system control apparatus 200.

Figure 6A illustrates an operation performed when the optical disk is inserted into the optical disk drive apparatus 204.

As described above, when the optical disk is inserted into the optical disk drive apparatus 204, the file structure operation section 211 reproduces the volume structure area 103 and the basic file structure area 104 and instructs the data read control section 236 to transmit the reproduced data to the file structure memory 221 (step S402 in Figure 5).

The file structure operation section 211 analyzes the basic file structure based on the data transmitted to the file structure memory 221. As a result, the file structure operation section 211 calculates the size of area in the logical volume space 100b that is available for recording based on the data reproduced from the space bit map area 113. The size of area is calculated by, for example,

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summing the number of sectors in the unallocated area 107. The calculation result is stored in the spare area information memory 224.

5           The file structure operation section 211 issues a Get Spare Info command to the optical disk drive apparatus 204 in order to inquire as to the remaining amount of the first spare area 102 (step S601).

10           The remaining spare area amount detection section 233 calculates the remaining amount of the first spare area 102 (e.g., the number of spare sectors that are available for replacement) by the method as described above in the description of the format operation, and the remaining  
15   spare amount reporting section 231 reports the calculation result to the system control apparatus 200 (step S602). The information indicating the remaining amount of the first spare area 102 is stored in the spare area information memory 224.

20           The spare area extension determination section 215 calculates the ratio (A/B) of the remaining amount (A) of the first spare area 102 with respect to the size of area (B) in the logical volume space 100b that is available for  
25   recording, and determines that the first spare area 102 should be extended if the ratio (A/B) is less than a predetermined ratio (e.g., 0.5%) (step S603).

30           The determination operation illustrated in Figure 6A is performed upon insertion of the optical disk before data is recorded thereon. The determination operation has features that the procedure of the determination operation is simple and that the implementation of the determination

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operation is easy.

Figure 6B illustrates an operation performed when recording a file. In the operation illustrated in Figure 6B, when a file is recorded on the optical disk, it is determined before recording the file whether or not it is necessary to extend the first spare area 102. Such a determination is performed based on the size of the data to be recorded and the remaining amount of the first spare area 102.

The file structure operation section 211 stores the data to be recorded on the optical disk in the data memory 223 and calculates the size of the data. The calculation result is stored in the spare area information memory 224.

The file structure operation section 211 issues a Get Event Status Notification command to the optical disk drive apparatus 204 in order to inquire as to the status of consumption of the first spare area 102 (step S604).

The remaining spare area amount detection section 233 calculates the remaining amount of the first spare area 102 by the method described above in the description of the format operation. If the remaining amount of the first spare area 102 is less than a predetermined size (e.g., 1 MB), the remaining spare amount reporting section 231 reports shortage information indicating the shortage of the first spare area 102 to the system control apparatus 200 (step S605). The shortage information is stored in the spare area information memory 224.

The spare area extension determination section 215 determines whether or not the first spare area 102 should

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be extended based on the size of the data to be recorded and the shortage information (step S606). For example, when the size of the data to be recorded is greater than the remaining amount of the first spare area 102, the spare area extension determination section 215 determines that the first spare area 102 should be extended.

With the determination operation illustrated in Figure 6B, it is possible to allocate the spare area according to the size of the file to be recorded. Therefore, the operation has features that it is possible to reasonably ensure the reliability of data recording, assuming that the frequency of occurrence of defective sectors is statistically substantially constant.

Figure 6C illustrates an operation performed in data transmission.

When a file is recorded on the optical disk, the data of the file is divided into a plurality of data portions. For example, when data having a size of 1 MB is recorded on the optical disk, the data is divided into a plurality of data portions each having a size of 32 kB.

A Write command is issued for each of the data portions. As a result, each of the data portions is transmitted from the system control apparatus 200 to the optical disk drive apparatus 204.

In the operation illustrated in Figure 6C, it is determined whether or not the first spare area 102 should be extended each time a data portion is transmitted.

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The file structure operation section 211 issues a Write command to the optical disk drive apparatus 204 for each of the data portions (step S607).

5           The data write control section 235 records the data portion transmitted from the system control apparatus 200 in a predetermined sector, and when a defective sector is detected, the defective sector operation section 234 performs a replacement operation for the defective sector.

10

          When the recording operation for the data portions is completed, the remaining spare amount reporting section 231 reports Status information indicating the execution result of the Write command to the system control apparatus 200 (step S608). The Status information includes information indicating the number of defective sectors which have occurred during the data transmission.

15

          The command status operation section 216 receives  
20   the Status information from the optical disk drive apparatus 204, and stores the information indicating the number of defective sectors which have occurred during the data transmission in the spare area information memory 224. The spare area extension determination section 215  
25   determines whether or not any defective sector has occurred during the data transmission based on the information stored in the spare area information memory 224. If any defective sector has occurred, the spare area extension determination section 215 determines that the first spare area 102 should  
30   be extended by the number of defective sectors (step S609).

The determination operation illustrated in Figure 6C has a feature that it is possible to effectively



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utilize the area of the optical disk that is available for recording. This is because the spare area can be extended each time a defective sector is detected, whereby the size of the area which is allocated as a spare area can be reduced.

5

In the above-described determination operation, the report by the remaining spare amount reporting section 231 of the remaining amount of the spare area to the system control apparatus 200 may be done in any form. For example,  
10 the remaining amount of the spare area may be represented in the form of flags or in the form of a remaining amount value.

Next, a method for extending the first spare  
15 area 102 and the second spare area 108 will now be described in detail with reference to Figures 1, 2 and 7.

Figure 7 is a protocol chart illustrating a procedure of an operation of extending the first spare  
20 area 102 and a second spare area 108. This operation is performed by the optical disk drive apparatus 204 and the system control apparatus 200.

When it is determined by the spare area extension  
25 determination section 215 that the first spare area 102 (or the second spare area 108) should be extended, the spare extension area detection section 212 determines the area to be allocated as an additional spare area based on the second spare area location information 143 stored in the  
30 file structure memory 221 (step S701).

When allocating the second spare area 108 for the first time, the second spare area 108 may be allocated in

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any area in the logical volume space 100b. However, when contiguous data of a large file size such as audio video data (AV data) is recorded on the optical disk, it is necessary to allocate a larger contiguous unallocated area 107. Therefore, when allocating the second spare area 108 for the first time, the second spare area 108 is desirably allocated starting from the end of the logical volume space 100a.

10           The spare sectors included in the second spare area 108 are used in an order such that spare sectors assigned with larger LSNs are used before those assigned with smaller LSNs. In other words, the defective sectors are replaced by the spare sectors in descending order of  
15   the LSNs assigned to the spare sectors.

When the second spare area 108 is extended, the second spare area 108 is extended in a direction along which the LSN decreases. When the second spare area 108 is  
20   extended, the area allocated as an additional spare area may be an area contiguous with the second spare area 108 or an area separated from the second spare area 108.

          The file structure operation section 211 determines  
25   whether or not the area to be allocated as an additional spare area is unallocated based on the space bit map information stored in the bit map memory 222 (step S702). If the area is unallocated, the process proceeds to step S704, and if not, the process proceeds to step S704 via step S703.  
30   This is because when the area to be allocated as an additional spare area is not unallocated (i.e., when data is already recorded in the area), it is necessary to move the data to another location before the area can be used as an additional

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spare area.

5       The file moving operation section 213 performs a  
file moving operation (step S703). In particular, the file  
moving operation section 213 examines the file structure  
of all the files on the optical disk to determine the data  
recorded in the area. Then, the file moving operation  
section 213 uses the space bit map information to search  
for an area to which it is possible to move the data which  
10       has already been recorded in the area to be allocated as  
an additional spare area, move the data according to the  
attribute of the data, and update the information of the  
file structure managing the moved data (step S703). In this  
way, an additional spare area is allocated.

15       Although not shown in Figure 7, the spare extension  
area allocation section 214 instructs the optical disk drive  
apparatus 204 to examine whether or not there is any  
defective sector in the area to be allocated as an additional  
20       spare area. When there is any defective sector in the area,  
the spare extension area allocation section 214 instructs  
the spare extension area detection section 212 to increase  
the size of the additional area, and returns the control  
of the process to step S701. Thus, the process is performed  
25       again from step S701.

30       When there is no defective sector in the area to be  
allocated as an additional spare area, the spare extension  
area allocation section 214 issues a Write command and  
transmits data for updating the file entry area 116 stored  
in the file structure memory 221 (step S704).

The data write control section 235 records the data

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transmitted from the system control apparatus 200 in the file entry area 116 (step S705). As a result, the second spare area location information 143 recorded in the file entry area 116 is updated.

5

The spare extension area issue section 217 issues an instruction to extend the spare area by using an Alloc Spare command. Specifically, the spare extension area issue section 217 issues an Alloc Spare command and  
10 transmits data for updating the second spare area location information 133 to the optical disk drive apparatus 204 (step S706).

The data write control section 235 updates the  
15 second spare area location information 133 stored in the defect management information memory 241 based on the data transmitted from the system control apparatus 200 (step S707).

20 Thus, when any data is recorded in the area to be allocated as an additional spare area, the data recorded in the area to be allocated as an additional spare area is moved to another area by analyzing the information of the file structure. In this way, the spare area can be extended  
25 even when data has been recorded in an area into which a spare area is to be extended.

When there is any defective sector in an area to be allocated as an additional spare area, the size of the  
30 additional spare area is increased according to the number of the defective sectors. Thus, it is possible to reliably ensure a spare area of a required size.